

CLAIMS

What is claimed is:

1. A pressure relief apparatus for reducing bounce of a hydraulic actuator, the pressure relief apparatus comprising:

a valve block with a first conduit for connection to the hydraulic actuator and a second conduit through which fluid is exhausted; and

a flow control assembly connected to the valve block, wherein the flow control assembly provides a first passage between the first conduit and the second conduit while pressure at the first conduit exceeds a first threshold and provides a second passage between the first conduit and the second conduit when pressure at the first conduit exceeds a second threshold level, the second passage being maintained open as long as pressure at the first conduit is greater than a third threshold level which is less than both the first threshold level and the second threshold level.

2. The pressure relief apparatus as recited in claim 1 wherein the first threshold level is substantially equal to the second threshold level.

3. The pressure relief apparatus as recited in claim 1 wherein the flow control assembly comprises:

a first relief valve which opens to provide the first passage between the first conduit and the second conduit; and

a second relief valve which opens to provide the second passage between the first conduit and the second conduit.

4. The pressure relief apparatus as recited in claim 3 wherein the first relief valve comprises a primary poppet which selectively engages and disengages a valve seat between the first conduit and the second conduit to open and close the first passage.

5. The pressure relief apparatus as recited in claim 3 wherein the second relief valve comprises a bleeder poppet which selectively engages and disengages a valve seat to open and close the second passage, wherein when the second passage is closed, pressure from the first conduit acts on a smaller area of the bleeder poppet than when the second passage is open.

6. The pressure relief apparatus as recited in claim 3 further comprising a hydraulically operated timer which causes the second relief valve to close the second passage after the second passage has been open for a predefined amount of time.

7. The pressure relief apparatus as recited in claim 3 further comprising a hydraulically operated timer which causes the second relief valve to close a given amount of time after the first relief valve closes.

8. The pressure relief apparatus as recited in claim 1 wherein the flow control assembly comprises:

- a housing connected to the valve block and having a bore;

- a first relief valve received in the bore and selectively engaging a first valve seat between the first and second conduits, the first relief valve disengaging from the first valve seat to open the first passage when pressure from the first conduit exceeds the first threshold;

- a passageway extending between the first conduit and an intermediate chamber within the housing;

- a second relief valve received in the bore and selectively opening and closing a fluid path between the intermediate chamber and the second conduit when pressure in the intermediate chamber exceeds a second threshold level and maintaining the fluid path open even though the pressure in the intermediate chamber decreases below the second threshold level.

9. The pressure relief apparatus as recited in claim 8 wherein the second relief valve is within the bore of the housing, and the intermediate chamber is formed in the bore between the first relief valve and the second relief valve.

10. A pressure relief apparatus which reduces bounce of a hydraulic actuator that is connected to an actuator conduit of a hydraulic system that also has a tank return conduit, the pressure relief apparatus comprising:

a housing having a bore;

a first relief valve within the bore of the housing and having an inlet port to receive fluid from the actuator conduit, the first relief valve further comprising a primary poppet selectively abutting a first valve seat and disengaging the first valve seat when pressure from the inlet port exceeds a first threshold to open a path between the inlet port and the tank return conduit;

a passageway extending between the inlet port and an intermediate chamber within the bore of the housing; and

a second relief valve within the bore and opening to provide a fluid path between the intermediate chamber and the tank return conduit when pressure in the intermediate chamber exceeds a second threshold level, remaining open even though the pressure in the intermediate chamber decreases below the second threshold level.

11. The pressure relief apparatus as recited in claim 10 wherein the first relief valve comprises a primary poppet slidably located within the bore and biased against the first valve seat by a spring.

12. The pressure relief apparatus as recited in claim 10 wherein the passageway extends through the primary poppet.

13. The pressure relief apparatus as recited in claim 10 wherein the second relief valve comprises:

a body within the bore of the housing and forming the second valve seat in the fluid path between the intermediate chamber and the tank return conduit; and

a bleeder poppet biased into engagement with the second valve seat, wherein pressure in the intermediate chamber acts on a smaller area of the valve member when the valve member engages the second valve seat than when the valve member is disengaged from the second valve seat.

14. The pressure relief apparatus as recited in claim 10 further comprising a hydraulic timer which causes the second relief valve to close regardless of pressure in the intermediate chamber.

15. A pressure relief apparatus which reduces bounce of a hydraulic actuator, the pressure relief apparatus comprising:

a housing having a bore;

a nose member received in the housing and defining an intermediate chamber in the bore, the nose member having internal chamber into which an inlet port and a first outlet port open, wherein a first valve seat is located between the inlet port and the first outlet port;

a primary poppet slidably received in the internal chamber of the nose member and having an aperture providing a fluid passage between the inlet port and the intermediate chamber;

a valve spring biasing the primary poppet against the first valve seat;

a body within the bore and separating the intermediate chamber from a control chamber, the body having a control aperture between the intermediate chamber and the control chamber;

a bleeder poppet within the bore of the housing and selectively opening and closing the control aperture, wherein pressure in the intermediate chamber acts on a smaller area of the bleeder poppet when the control aperture is closed than when the control aperture is open, thus a greater pressure is required in the intermediate chamber to open the control aperture than is needed thereafter to maintain that open condition; and

a tank passage connecting the control chamber to a second outlet.

16. The pressure relief apparatus as recited in claim 15 further comprising a hydraulically operated timer valve which enables fluid to flow from the control chamber through the tank passage to the second outlet for a defined interval of time.

17. The pressure relief apparatus as recited in claim 15 further comprising hydraulically operated timer valve that comprises:

a timer spool moveably located in the bore with the control chamber on one side and a dwell chamber on an opposite side, the timer spool having an orifice extending between the control chamber and the dwell chamber, wherein the spool has a closed position which blocks fluid flow from the control chamber into the tank passage and has an open position which permits fluid to flow from the control chamber into the tank passage;

a feed passage connecting the internal chamber of the poppet to the dwell chamber;

a check valve in the passage allowing fluid to flow from the internal chamber of the nose member to the dwell chamber; and

a timer spring biasing the timer spool into the closed position.